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SOD, TILLAGE AND FERTILIZERS FOR THE APPLE ORCHARD

A Ten-Year Summary

By J. H. GOURLEY

NEW HAMPSHIRE COLLEGE
OF
AGRICULTURE AND THE MECHANIC ARTS
DURHAM, N. H.

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SOD, TILLAGE AND FERTILIZERS FOR THE APPLE ORCHARD.

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SUMMARY.

1. This paper presents a ten-year average of an experiment in a mature Baldwin apple orchard, dealing with various cultural and fertilizer treatments.
2. The more practical aspects of the work are dealt with in this report, such as the yield and growth of the trees and size of fruit in the various plots.
3. The trees growing in sod have not yielded sufficiently well to warrant the use of the land for orcharding and they have made such inferior growth most seasons as to make them less able to withstand the destructive influences of weather and parasites.
4. Tillage every other year resulted in decided benefit to the trees and under certain farm conditions in New Hampshire might prove satisfactory, but better results obtain when tillage is followed annually.
5. Clean cultivation, without the use of green crops, has proven to be a successful method in the reclamation of a run-down orchard, increasing the yield nearly 100 per cent and increasing the growth and general vigor of the trees. It has shown evidence, however, that it could not be continued over a long period of time since at the end of the ten-year period the trees are not making as good an average growth as at the end of the five-year period which must be interpreted as a decline.
6. Tillage with cover crops has proven to be a slightly better system to follow in this orchard than clean tillage, and has given practically as good results as any treatment followed. The cover crops are not being maintained, however, and show decided evidence of the need of additional fertility. This plot is not in quite as high a state of vigor at present

as during the earlier years of the experiment, thus indicating a slight decline but less so then the clean tillage plot. Commercially this has been the most profitable plot in the orchard and can well be emulated in the rundown orchards throughout the state.

7. The fertilized plots have failed to respond to their treatment in yield of fruit as they have made very slight gains and in some cases none over the first stimulus of the cultivation. In growth they have responded better but it was not distinguishable to the eye until after the sixth year when the larger size of trees was noticeable and also the darker green color of the foliage. The difference in favor of any of the combinations of complete fertilizer used in the different plots is not preponderant.
8. The fertilizer combination which is richest in potash has given the largest apples throughout the experiment and the general quality is perhaps somewhat better than in the other fertilizer plots. This difference is not especially outstanding, however.
9. The experience with this orchard shows in a most emphatic way the importance of selecting a proper site for an orchard, for the losses from frosts and freezes in a poorly located orchard are disastrous.
10. Lime has had no obvious effect upon this orchard.

FIG. 1—VIEW IN WOODMAN ORCHARD.

INTRODUCTION.

From time to time during the past ten years reports have been issued dealing with various phases of our experiments in the Woodman Orchard. The primary object of these experiments has been to study the factors which influence the formation of flower buds and conversely those which tend to produce only vegetative ones. And truly it can be said that the work has only begun, since so many new phases of the problem arise that are closely related to those already under investigation. The present paper, however, deals more particularly with the yield and growth of the trees which have been under the various cultural treatments and also with the results from the continuous use of fertilizers, or in other words with the more practical phases of the work. While the work was begun in 1908 the treatments this first year could scarcely affect materially the yield, hence the ten-year period from 1909–1918 is used in summarizing the work, although the records of 1908 are cited for comparison. For the effects of these treatments on the soil itself and upon the internal responses of the tree, the reader should consult previous papers.*

In reviewing this work it should be remembered that New Hampshire conditions are in the mind of the writer for doubtless some of the conclusions would lose their point or at least seem superfluous if applied to some other sections. For instance it does not seem necessary for anyone to prove that growing apple trees in sod is usually not a good practice, for that was demonstrated years ago by various experiment stations as well as individuals and yet it is the prevailing practice in so many quarters that repetition of the value of other methods of culture seems justified. True, experimental evidence may not change the practice because of good or poor reasons for continuing the old, yet we repeat that our Experiment Station can give the growers no more valuable advice than to follow the practices which have proven successful in this orchard, modified, of course, to suit their own conditions. In our experience of the past ten years the sod section of the orchard has borne uniformly so poorly that it would not pay commercially and the tilled portions of the or-

* N. H. Exper. Sta. Tech. Bul. Nos. 9, 11 and 12.

chard have yielded sufficiently well, even under most adverse conditions, to be profitable, that is, there is here the difference between profit and loss. It would be useless for us to attempt to deny the fact that there are sod orchards in the state that pay or to argue that there are not certain advantages that pertain to growing trees in sod, but these are the exception and not the rule.

THE EXPERIMENT.

A description of the orchard together with the plots into which it has been divided has been published in connection with the various reports on this work which have appeared previously, hence only a brief description of the plots need be repeated.

Schedule of Treatment of Plots.

Crimson clover is used as a cover crop in every case.* Seed is sown July 10 at the rate of 20 pounds per plot. In seeding plots 2 and 3 the following mixture is used:

10 pounds red clover,
5 pounds white Dutch clover.

Plot 1—Sod. To remain permanently in sod. Grass to be mown when inconveniently long and allowed to remain on the ground. No fertilizer is applied.

Plot 2—Cultivated the odd year, cover crop sown July 10, seeded the even. No fertilizer is applied.

Plot 3—Cultivated the even year, cover crop sown July 10, seeded the odd. No fertilizer is applied.

Plot 4—Clean Cultivation. This plot is plowed every spring and cultivated every two weeks until September 1. No cover crop is sown and no fertilizer is applied.

Plot 5—Cultivation and Cover Crop. This plot is plowed each spring and cultivated every two weeks. A cover crop consisting of 20 pounds of crimson clover is then sown. No fertilizer is applied.

Plot 6—Cultivation and cover crop with the following complete fertilizer per tree:

2 pounds nitrate of soda,
4 pounds sulphate of potash,
7 pounds basic slag.

Plot 7—Cultivation and cover crop, with the following complete fertilizer per tree:

2 pounds nitrate of soda,
4 pounds sulphate of potash,
8½ pounds acid phosphate.

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* One season winter vetch was used with the clover and in another buckwheat was used.

Plot 8—Excess Phosphorus. Cultivation and cover crop with the following complete fertilizer per tree:

2 pounds nitrate of soda,
4 pounds sulphate of potash,
17 pounds acid phosphate.

Plot 9—Excess Nitrogen. Cultivation and cover crop, with the following complete fertilizer per tree:

6 pounds nitrate of soda,
4 pounds sulphate of potash,
8½ pounds acid phosphate.

Plot 10—Excess Potassium. Cultivation and cover crop, with the following complete fertilizer per tree:

2 pounds nitrate of soda,
10 pounds sulphate of potash,
8½ pounds acid phosphate.

GENERAL RESULTS.

Before taking up the individual plots it might be more convenient to examine the results as a whole. The general summary for ten years is therefore first considered.

Weather Conditions.

In the discussion of this work, especially if viewed from a commercial standpoint, it should first be pointed out that the location is not favorable for such an experiment because the true behavior of the trees is not fairly reflected in the yield of fruit which has been obtained. In the ten years here reported we have had only four good crops of fruit (1910, 1912, 1914, 1916) due pretty largely to frosts and freezes. For instance in 1913 a severe frost reduced the crop to practically nothing although the first two plots were not so badly damaged. Our records show that the estimate made of the percentage of blossoms in all plots in 1913 was within 4 per cent as high as in 1910 when we had a full crop. We have previously considered that the orchard would have borne at least a half a crop that year but under favorable conditions it might have been considerably more than that. While these estimates of the percentage of blossoms cannot be exact yet they are certainly indicative. Again in 1915, when at least a third of a crop appeared likely, the entire crop was lost by frost which again cuts down our average appreciably. In 1917 the orchard did not blossom very full, the average estimate of all

plots being only 15 per cent, but in addition we had rain or very cloudy weather during practically the whole of the blooming period, hence reducing the set of fruit still further. In 1918 our trees suffered so severely from the winter that the terminals were nearly all killed, hence destroying the blossom buds and reducing the crop materially when we had every evidence of a maximum yield. This year again the first few plots were not injured so severely.

Thus in figuring the average yield per acre for the past ten years it must be remembered that the location of this orchard is not good and in a more favorable place we might expect the yield to be at least double what it now is. Such an explanation seems not only just but desirable before reviewing this work.

Yield Under Sod and Tillage Methods.

As indicated above the trees in the sod plot (Plot 1) have not yielded sufficient fruit to justify the practice, although if there were nothing to compare them with we might feel that they did very well for the trees often yield a moderate crop. On the other hand, the plot which has had clean cultivation (Plot 4) has responded remarkably well to tillage, and at the end of the ten-year period this plot averages 94 per cent higher in yield than the sod plot. The plot (Plot 5) which has been sown to a cover crop annually averages 98 per cent greater in yield than the sod plot and has made a good growth throughout the entire period.

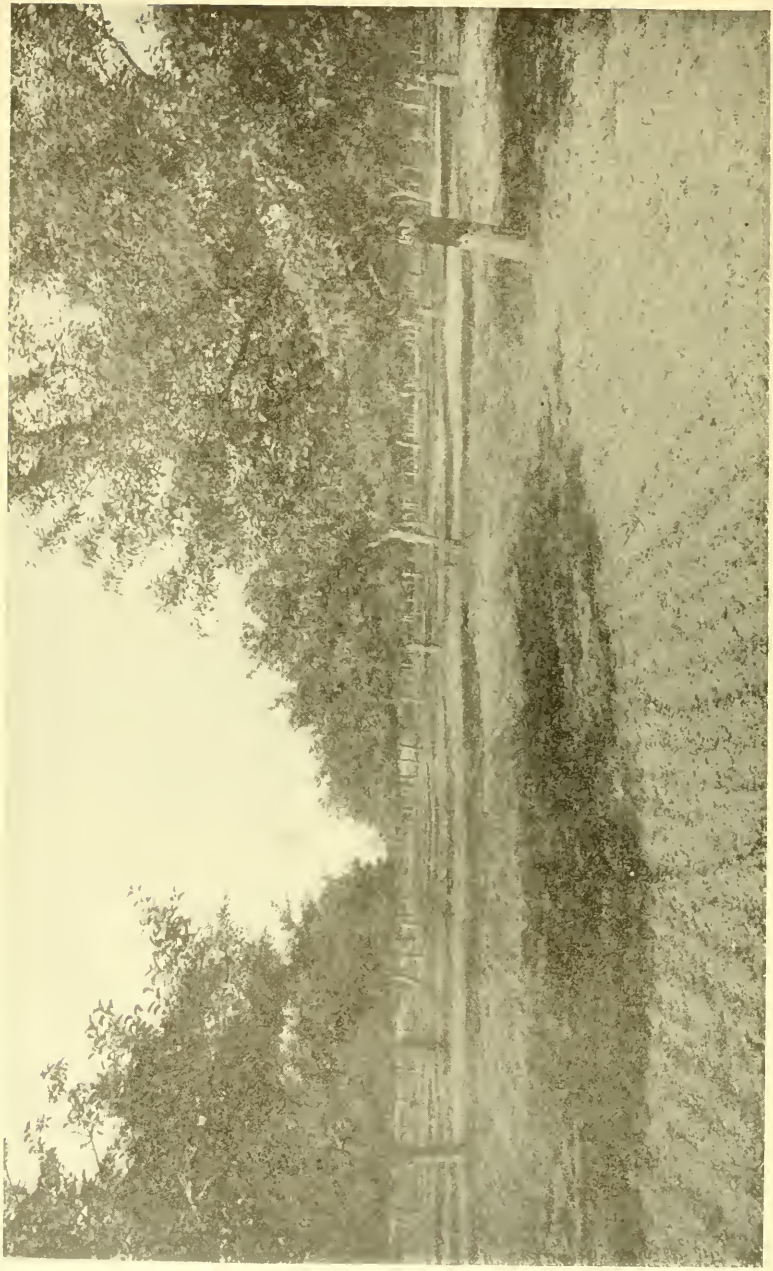

FIG. 2—VIEW IN FERTILIZER PLOTS, 1909.

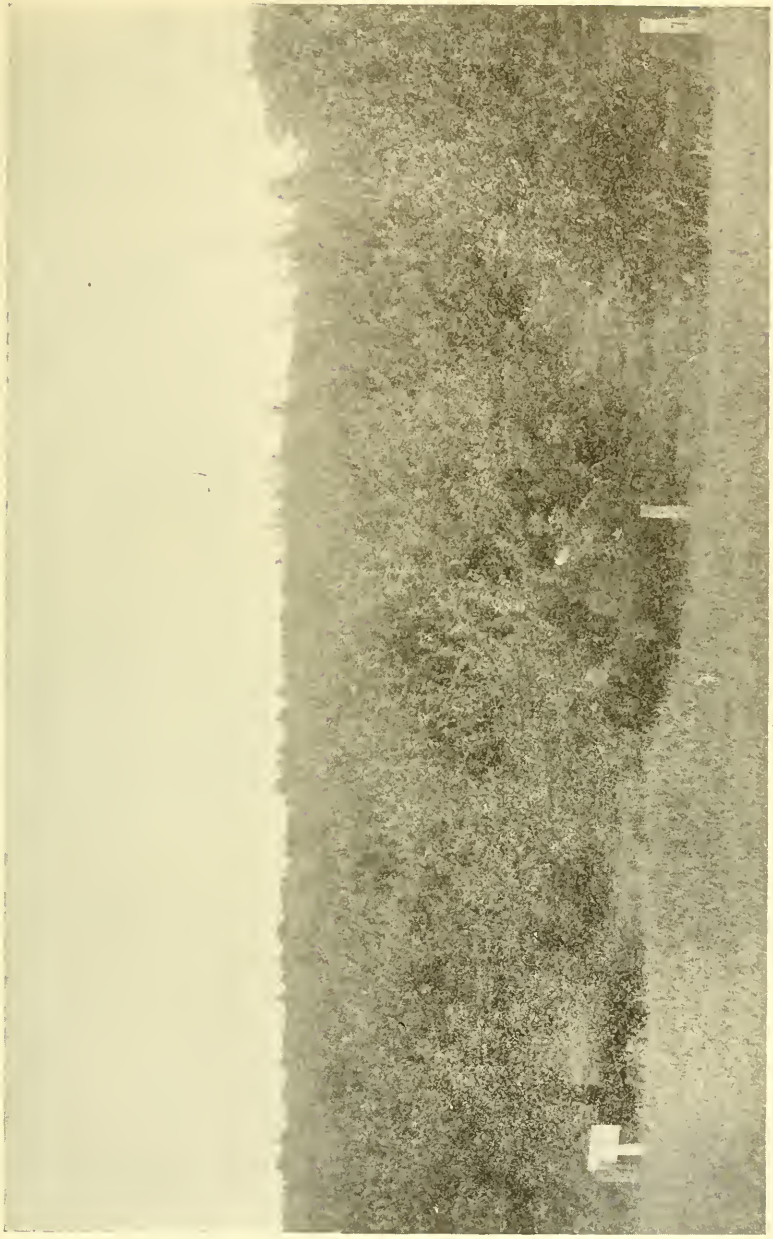

FIG. 3—VIEW IN FERTILIZER PLOTS, 1918, SHOWING THAT BRANCHES ARE NEARLY MEETING.

Effect of Fertilizers.

Of special interest in this work are the results of the continuous use of fertilizers. In an earlier paper* we stated that "a five-year average of the results from this orchard do not show an increase in the yield of the fertilized plots over those receiving good culture, or a sufficient increase in the growth of the trees to warrant the use of fertilizers. . . . What the future may reveal in this experiment cannot be told." After another five years it is well to examine the records and see what changes have come about. Here we again find that no special increase in yield has been brought about although the orchard is developing in that direction. For instance in 1914 one of the fertilized plots (Plot 6) bore about 2 per cent more fruit than a similarly cultivated plot which received no fertilizer (Plot 4) and in 1916 (the only other year in the period in which we had a crop) one of the fertilized plots (Plot 10) yielded 12 per cent more than Plot 5 which was the highest yielding unfertilized plot that year. On the other hand we have had a decided increase in growth in the fertilized plots. Yet at the end of eleven years' work we are still out of pocket as a result of applying the fertilizers although we think we can see some financial gain in the next five-year period. We do not mean by this statement that the orchard has not been benefited for such is not the case, but only that if the books were balanced today after eleven years of fertilization we would have the fertilizer bill on our hands with no increase in yield to liquidate it.

* N. H. Exper. Sta. Bul. No. 168.

TABLE No. 1.

Influences of Treatments on Yield, Growth and Size.
(Ten-Year Average, 1909–1918.)

Plot	Treatment	Yield: Pounds	Growth: Inches	Size: Per cent No. 1	Quality:* Rank
1	Sod	135	5.09	54	1
2	Tilled alternate years	157	5.41	60	2
3	Tilled alternate years	225	6.82	62	3
4	Clean cultivation	262	7.31	55	10
5	Tillage and cover crop	268	8.21	56	
6	Tillage, cover crop and complete fertilizer	258	9.08	56	5, 6, 7, 8, 9 indeterminate.
7	Tillage, cover crop and complete fertilizer	210	9.14	57	
8	Tillage, cover crop and complete fertilizer	199	9.18	61	
9	Tillage, cover crop and complete fertilizer	219	9.43	66	
10	Tillage, cover crop and complete fertilizer	240	9.22	71	4

* This refers to appearance rather than *eating* quality.

In Table No. 2 we have the average yield per tree in pounds in each plot for the ten-year period and the same is shown graphically in Fig. 1. By referring to Table No. 2 where the yield in pounds per tree has been converted into bushels per acre we find that the plots which have been cultivated annually but without fertilizer (Plots 4 and 5) have yielded on the average 191 and 195 bushels respectively or 64 and 65 barrels per acre as compared with 99 bushels or 33 barrels per acre on the sod plot which means practically 100 per cent increase. Also we see that these two tilled plots have averaged the highest in yield for the ten years, although some of the fertilized plots have surpassed them in some years. While there is no apparent reason why the fertilized plots should yield less per tree on the average than the unfertilized tilled plots, for the trees appear equally good and recently have appeared better, yet it is most notable that they do not yet yield more. While there is a tendency for these plots to increase in yield such an increase in any one year is not particularly conspicuous as indicated above. Yet the continually increasing size of the trees should bring about a substantial increase in yield during the next decade.

TABLE No. 2.

Average Annual Yield in Pounds per Tree (1909–1918).
Woodman Orchard.

Year	Plots									
	1	2	3	4	5	6	7	8	9	10
1909	23	16	27	26	21	15	18	20	23	8
1910	120	306	620	451	634	496	518	450	455	612
1911	164	190	39	122	29	77	35	52	42	29
1912	99	184	378	459	501	506	462	400	401	364
1913	184	213	77	100	27	41	14	33	23	27
1914	58	164	416	669	647	682	568	477	657	664
1915	Crop Destroyed by Frost									
1916	278	303	434	467	472	416	301	339	336	530
1917	59	33	2	46	21	68	73	108	155	68
1918	373	168	261	283	330	284	119	111	106	107
10-Yr. Av.	135	157	225	262	268	258	210	199	219	240
Percentage increase over Plot 1.....		16	66	94	98	91	55	47	62	78

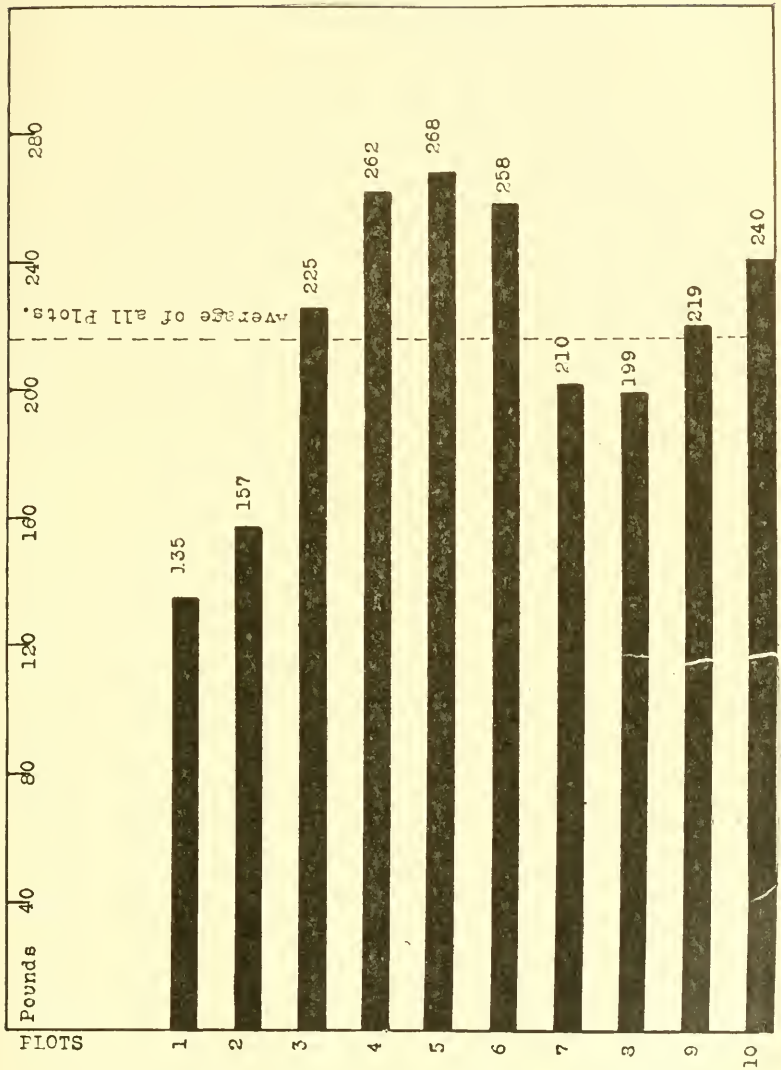

FIG. 4—CHART SHOWING RELATIVE YIELDS IN POUNDS FROM THE 10 PLOTS TEN-YEAR AVERAGE.

TABLE No. 3.

Average Annual Yield per Acre in Bushels (1909–1918).
Woodman Orchard.

Year	Plots									
	1	2	3	4	5	6	7	8	9	10
1909	16.77	11.66	19.68	18.96	15.31	10.94	13.12	14.58	16.77	5.83
1910	87.50	223.12	452.08	328.85	462.29	361.66	377.71	328.12	331.77	446.25
1911	119.58	138.54	28.43	88.95	21.14	56.14	25.52	37.91	20.62	21.14
1912	72.18	134.16	275.62	334.68	365.31	368.95	336.87	291.66	292.39	265.41
1913	134.16	155.31	56.14	72.91	19.68	29.89	10.20	24.06	16.77	19.68
1914	42.29	119.58	303.33	487.81	471.77	497.29	414.16	347.81	479.06	484.16
1915	Crop Destroyed by Frost									
1916	202.70	220.93	316.45	340.52	344.16	303.33	219.48	247.18	245.00	386.46
1917	43.02	24.06	1.46	33.54	15.31	49.58	53.23	78.75	113.02	49.58
1918	272.00	122.50	190.31	206.35	240.62	207.08	86.77	80.93	77.29	78.02
10-Yr. Av. ...	99.02	114.98	164.35	191.26	195.56	188.48	153.71	145.10	160.27	175.65

Size of Fruit.

After considering the gross yield of fruit per tree and per plot we are next interested in the size of fruit produced on each plot. We determine this by sorting the fruit from each tree into three grades, namely No. 1, No. 2 and Culls, which means that all fruit which measures $2\frac{1}{2}$ inches or over goes into No. 1 grade with the exception of blemished fruit, and all fruit from 2 to $2\frac{1}{2}$ inches is put into the No. 2 grade and fruit not included in these two grades are classed as Culls. The results are seen in Table No. 4. In Table No. 3 we find that Plot 10 stands highest in per cent of No. 1 fruit for both the five- and ten-year period, while Plot 9 is next highest, and Plot 1 ranks lowest each year. The other plots exchange places to some extent as is seen below.

TABLE No. 4.

Respective Rank of the Plots in Percentage of No. 1 Fruit.
Woodman Orchard.

	Plots									
	1	2	3	4	5	6	7	8	9	10
1st 5-Yr. Period	10	4	6	8	9	5	7	3	2	1
2nd 5-Yr. Period	10	5	3	9	7	7	6	4	2	1

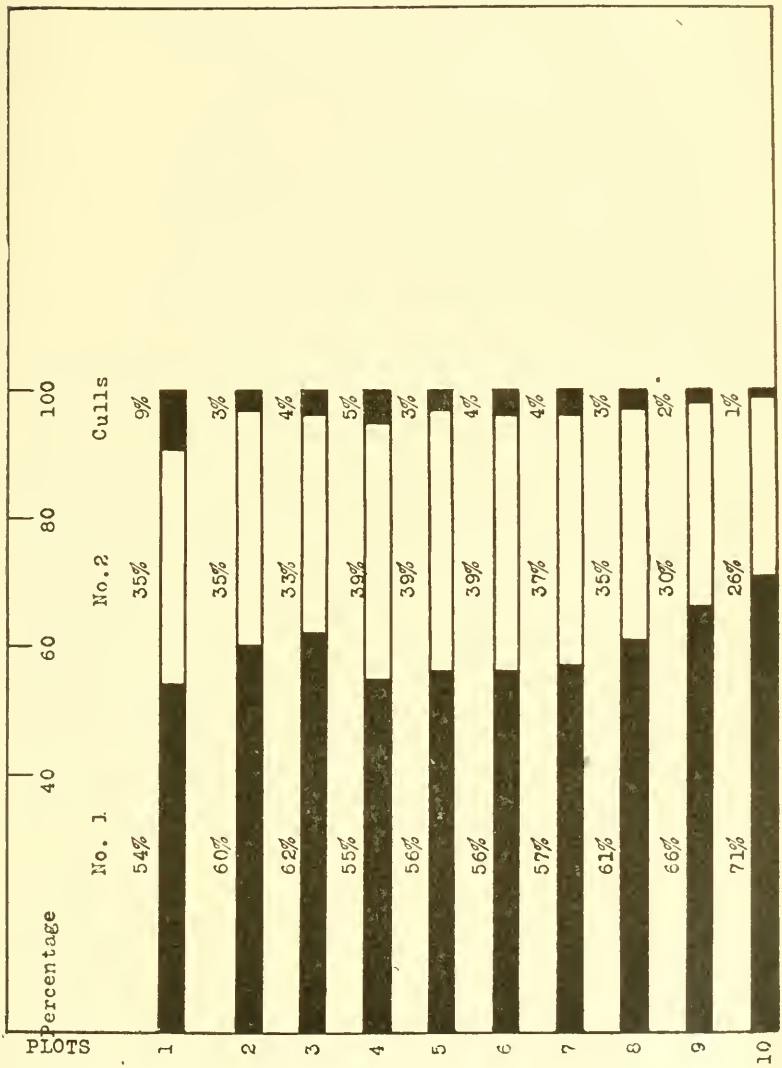

FIG. 5—CHART SHOWING THE PERCENTAGE OF NO. 1, NO. 2 AND CULL APPLES FROM THE 10 PLOTS. TEN-YEAR AVERAGE.

TABLE No. 5.

Size of Fruit.

Percentage of No. 1, No. 2 and Culls in Each Plot.
(Eight-Year Average, 1910–1918.)

Grade	Plots									
	1	2	3	4	5	6	7	8	9	10
No. 1	54	60	62	55	56	56	57	61	66	71
No. 2	35	35	33	39	39	39	37	35	30	26
Culls	9	3	4	5	3	4	4	3	2	1
Percentage Increase of No. 1 Apples over Plot 1		11	14	1	3	3	5	12	22	31

Growth of Trees.

When we examine the twig growth in this orchard we find that it parallels the yield in the first five plots only, for when we reach the fertilized ones (6–10) we find that they have been materially affected by the treatments. Here we find that at no time in the ten years have the trees in any of the unfertilized plots grown as much as those in the fertilized ones. But in the past five years the increase in the latter plots has been much more noticeable. The following figures give the difference between the best growing unfertilized and fertilized plots each year. This of course would not always be the same plot in either case as shown by Table No. 5, but it brings out the growing difference between the two sets of plots as the experiment continues.

Difference in Inches Between the Best Growing Unfertilized and Fertilized Plots Each Year.

1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
.02	.81	.70	.80	.83	4.67	1.80	2.80	2.70	2.47

Plot 9 which is treated with more nitrogen than the other plots has made the greatest average growth for the ten-year period, being 85 per cent greater than the sod plot, and 14 per cent greater than Plot 5, the strongest of the unfertilized plots. We should not assume that excessive growth is desirable and that the success of the work could be measured by the greatest growth obtained for there are indications that more growth is being made in some plots than is desirable.

The growth of the trees is feeble in 1918 following the severe winter which reduces the average somewhat.

Trunk Growth.

Since 1913 the growth of the trees has been measured by the diameter of the trunks as well as by the length of the annual terminal growth. The method employed is to select a spot on the trunk at a height of two feet from the ground and mark it with white paint, and also select a spot at right angles to the first one, likewise marking with paint so that the measurement can be taken each year at the same point. A caliper is used in making the measurements and the two diameters averaged for each tree each season, thus giving a better figure than if just one measurement were taken.

Table No. 6 shows the average diameter in inches of the trees in each plot in 1913 and the average increase which each plot has made. Here again we find Plot 9 and also Plot 8 showing the highest average growth for the five-year period which is 83 per cent greater than the sod plot, while it will be recalled that in twig growth Plot 9 averaged 85 per cent greater than the sod plot for the ten-year period.

TABLE No. 6.

Average Annual Twig Growth per Tree in All Plots.
Length in Inches.

Year	Plots									
	1	2	3	4	5	6	7	8	9	10
1909	4.59	4.08	5.34	6.29	8.31	8.33	7.08	6.85	8.02	7.24
1910	4.15	6.78	6.95	8.79	10.19	11.00	9.85	10.14	10.93	9.85
1911	3.21	6.69	7.55	8.43	8.19	9.13	7.68	7.94	8.20	7.87
1912	4.79	5.93	7.46	8.43	8.92	9.72	8.64	8.55	9.26	8.93
1913	5.76	6.23	8.78	9.03	9.03	9.86	10.13	9.47	8.65	9.65
1914	4.7	4.7	3.98	4.9	6.9	8.92	10.3	10.44	11.57	10.43
1915	6.4	5.1	9.65	7.18	10.3	9.8	11.0	11.9	11.9	12.1
1916	4.9	5.6	7.4	7.7	7.9	9.4	10.6	9.9	9.7	10.7
1917	8.1	5.2	8.3	9.1	8.9	7.9	11.8	10.9	10.3	11.5
1918	4.34	3.83	2.84	3.27	3.54	6.8	4.38	5.72	5.82	3.98
10-Yr. Av.	5.09	5.41	6.82	7.31	8.21	9.08	9.14	9.18	9.43	9.22
Percentage increase over Plot 1.....		6	34	43	61	78	79	80	85	81

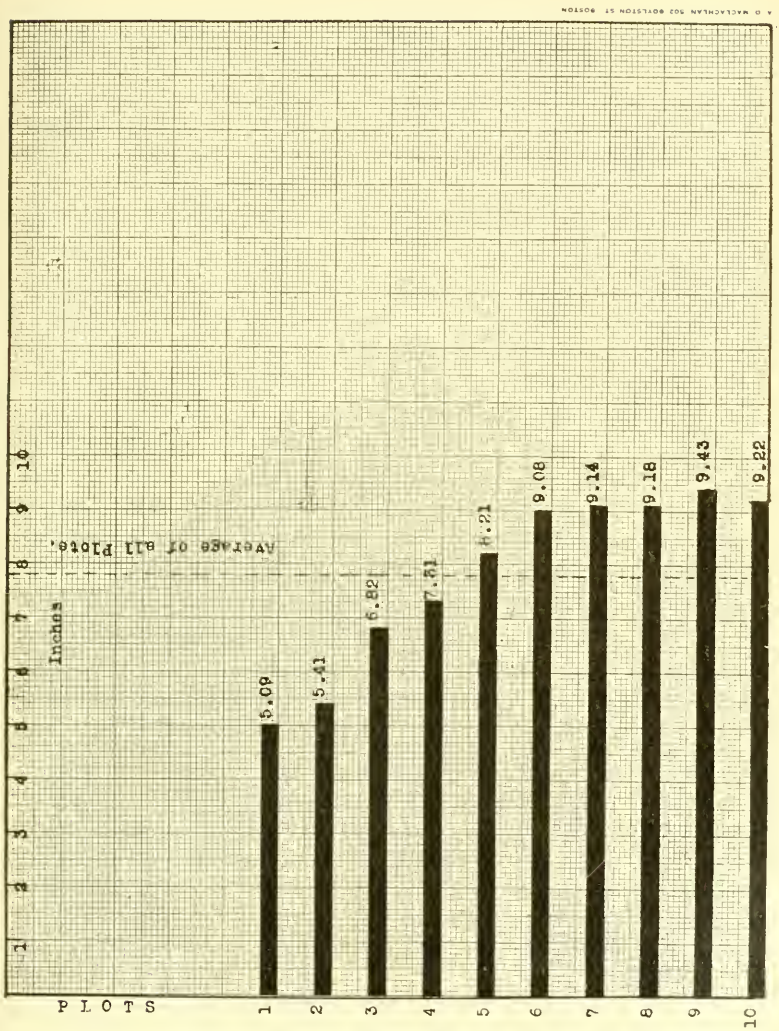

Fig. 6—Chart Showing the Comparative Twig Growth in the 10 Plots. Ten-Year Average.

TABLE No. 7.

Average Diameter Increase (1913–1918).
Woodman Orchard.
Inches.

Plot	1913 Diam.	1914 Gain	1915 Gain	1916 Gain	1917 Gain	1918 Gain	5-yr. Av.	Percentage Increase over Plot 1
1	9.78	.38	.25	.32	.08	.49	.30	....
2	10.33	.45	.37	.19	.06	.60	.33	10
3	11.05	.48	.42	.28	.28	.59	.41	36
4	10.59	.42	.45	.35	.05	.54	.36	20
5	10.80	.59	.41	.54	.22	.44	.44	46
6	10.55	.63	.51	.47	.53	.41	.51	70
7	10.59	.73	.44	.62	.26	.58	.53	76
8	10.94	.74	.33	.73	.30	.66	.55	83
9	10.66	.71	.46	.64	.29	.64	.55	83
10	11.18	.74	.44	.77	.39	.28	.52	73

Growth of Cover Crops.

It should be noted that in recent years the cover crops on the fertilized plots are very notably heavier in growth than on Plot 5 and also it should be noted that the cover crop on Plot 5 is becoming poorer each year. Thus we conclude that the ever increasing amount of green manure plowed into the ground is affecting beneficially the growth of the trees in the fertilized plots but no special data have been collected to show this matter, although it is quite noticeable to one acquainted with the orchard. This of course is complicated with the fertilizer treatments. On the section of the orchard where lime is applied annually there has been little evidence of its effect. In one year (1916) only was the clover on this section distinguishable from the other sections, but that year it was quite marked.

DISCUSSION OF PLOTS SEPARATELY.

Considerable that might be said in a separate discussion of the plots has already been canvassed in the foregoing remarks, however at the risk of repetition the behavior of the individual plots will be taken up briefly.

Plot 1.

Throughout our work this plot has served as our check plot since it has been neither cultivated nor fertilized. We have constantly advised against such treatment for an orchard because of the comparative lower yields and of the unsatisfactory growth which has resulted. There is, nevertheless, less variation in the yield from year to year than in the more intensely cultivated sections of the orchard, being more consistent than any other plot except Plot 2 which is tilled every other year. It also has been increasing somewhat in both yield and growth as the years proceed, for what reason we cannot be sure, but probably because the grass is kept cut so that there is less danger from this source than formerly when the soil was exhausted from letting the land produce a crop of hay each year. When the grass is cut it has been left to lie where it falls and the result is that a thin mulch has accumulated which may be resulting in a benefit to the trees. This plot has suffered much less from frosts and freezes than the fertilized plots at the other end of the orchard since the surrounding land is more level and not because of later blooming. This benefit was noticeable practically every time a frost occurred during the period of blooming. There was noticeably less injury to the trees as a result of the low temperatures of the winter of 1917–1918 than in the stronger growing part of the orchard; this, however, was probably in a large measure due to the condition of the trees rather than to location, since the orchard is quite level.

The average yield for this plot for ten years is 33 barrels per acre and the highest yield in any one year was in 1918 when it yielded 91 bushels per acre and the next highest yield was in 1916 when it yielded 67 bushels per acre, about half the average yield of Plot 5. This plot also averages the lowest per cent of No. 1 apples and the highest per cent of Culls of any plot in the experiment. On the other hand the finest looking apples have almost invariably come from this plot as well as the next two plots which are seeded down to grass every other year. This seems to be the deciding factor with many growers for they desire a highly colored apple and apparently do not appreciate the big expense in yield which they suffer as a result.

While not exactly germane to our discussion it might be well to record here that our most serious damage from canker (Sphaeropsis Malorum) is in this plot since the trees are not able to outgrow the trouble as in the more vigorous growing tilled and fertilized plots.

Plots 2 and 3.

Since these plots are treated alike they should be discussed together. They alternate, one being tilled one year and the other the next and are seeded down to clover and grass when not under tillage. For some reason not apparent Plot 3 has usually borne much heavier crops than Plot 2, and averages 42 per cent increase in yield for the ten years which is nearly as great an increase as there is in some other plots which have a radically different treatment. There are, however, only seven trees in this plot and since they happen to be good trees it gives the plot a somewhat unfair advantage, since Plot 2 has sixteen trees part of which are in rather poor condition. While it seems somewhat unreasonable to average two plots together which have responded so differently, we feel forced to consider them together since their treatments have been the same. The average yield of the two plots is 139.66 bushels or 46½ barrels per acre. The difference in growth is not so marked since Plot 2 has averaged 5.41 inches in terminal growth and Plot 3 increased this by 26 per cent making 6.82 inches terminal growth per year. This system of tilling the land every other year has yielded much better results than the sod plot and would be preferable to it, yet the general appearance and vigor of the trees is not equal to the plots which are tilled annually.

The quality of fruit from these two plots is good, being high in color and of good form for the Baldwin variety.

Plot 4.

In some respects this plot is one of the most interesting in the series. The soil of this plot is light, running to sand and gravel on the south half of the plot, and the land prior to being plowed in 1908 had been subjected to a haying system wherein the crop of hay was removed each year without any rotation of crops or tillage, and since 1908 no cover crops or fertilizers of any kind

have been returned to the soil, and yet this plot has averaged next to the highest in yield in the series. Furthermore the difference in yield between this plot and the highest yielding one is negligible. This is practically the system of soil culture followed in many places in the Western States but which has recently proven to be a deficient system. During the first few years of the experiment the trees in this plot made a growth which compared favorably with the fertilized plots but the past five years the growth of these trees has been less than formerly, in fact they have steadily declined as compared with the fertilized plots. This is perhaps to be expected for obviously such a system is contrary to all agricultural teachings and it could be but a matter of time until a deficiency appeared. In yield this plot has produced on the average 262 pounds of fruit per tree or 191.26 bushels per acre, which is an 84 per cent increase over Plot 1. In growth it has averaged 7.31 inches twig growth per year or a 43 per cent increase over Plot 1. In size of fruit it ranks low averaging 55 per cent of No. 1 apples, which is only 1 per cent higher than Plot 1 and is 16 per cent less than Plot 10. This could doubtless be corrected somewhat by thinning but should not be considered lightly for it is likely that it could be bettered by an increase of fertility to the soil. However Plots 2 and 3 which receive no fertilization have averaged as high in percentage of No. 1 fruits as the average of all the fertilized plots thus indicating that the size of the crop borne by the trees is a large factor in the matter. In general we must conclude from the tendencies of this plot that for a long-time consideration of this orchard soil either vegetation or fertilizers would be necessary to maintain and increase its efficiency although tillage alone for a period of years will benefit the orchard in a most striking manner, increasing its yield and general vigor almost as greatly as would result from the addition of applications of commercial fertilizers. But under all circumstances, so far as we now know, we would recommend the treatment of the next plot (Plot 5) in preference to this one to all those who expect to till their orchards.

Plot 5.

The practice followed in this plot is a standard one thoughout the country, that is, simply tillage early in the season followed by

a seeding to a cover crop. The general response of the trees in this plot is so similar to those in Plot 4 that they can well be compared. The difference in treatment is that in Plot 4 the tillage continues every two weeks until September 1 and no cover crop is sown, while in Plot 5 the tillage ceases July 10 and a cover crop is sown. The appearance of the trees in these two plots is much the same, also the type of fruit produced is much the same. The actual yield has not varied markedly throughout the ten years, the average being but 6 pounds of fruit per tree. The growth is a little better in this plot, averaging 12 per cent greater for the ten years. This is the only tangible or practical advantage which can by any interpretation be credited to the cover crop. Probably this difference in growth is not incidental since our study of nitrification in the two soils shows a markedly higher content in Plot 5 than Plot 4 (nearly 100 per cent), and also 2 per cent higher moisture content, hence we would expect a better vegetative growth as a result. This must be said, however, that recently the cover crop on this plot is meagre, scarcely enough to make much vegetable matter in the soil, and where fertilization is used in subsequent plots the cover crop is very much heavier. This difference did not obtain the first five or six years. In attempting to draw conclusions as to the value of a cover crop in an orchard from these two plots the above stated conditions must be recognized.

The actual yield of this plot for the period is 268 pounds per tree per year or 195.56 bushels per acre. The size of the fruit runs about the same as for Plots 4, 6, and 7, being 56 per cent of No. 1 apples. The actual growth as indicated by the terminal twig growth is 8.21 inches per year which is a fairly satisfactory growth for mature, bearing Baldwin trees in this section. The foliage is of good size, and a healthy green color. In general it must be said that the treatment of this plot has made a remarkable showing and gives good evidence that the unplowed Baldwin orchards in this state would make a notable improvement if such a treatment were given them.

Plot 6.

Beginning with this plot we take up the five plots which have received annual applications of a complete fertilizer which are to

be compared with the first five plots which received no fertilizer treatments whatever. This plot received annually the following quantities of fertilizer per acre:

70 pounds nitrate of soda,
116 pounds basic slag,
52.5 pounds sulphate of potash.

The fertilizer was broadcast over the entire soil area of the plot, and was applied usually about the time the trees were in bloom or a few days later, but on one occasion, due to very wet land, it was not applied until late in June.

An effort has been made from time to time to discover any particular effect of the basic slag on the appearance of the fruit, growth of tree, foliage, fruit buds, etc., but nothing of a striking nature could be seen or that would in any way set it off from the other fertilized plots. The yield of this plot averages the highest of the five fertilized plots and was the highest in yield per tree in five of the ten years. It is not yet clear whether this is due to the basic slag or to some other cause. The yield is practically the same as in Plots 4 and 5, being 258 pounds per tree, or 188.48 bushels per acre, as compared with 262 and 268 pounds respectively for the other two mentioned. In size the fruit ranks the same as in Plot 5, thus showing no superiority in this regard.

In growth, however, this plot shows a superiority over the unfertilized plots and averages 9.08 inches twig growth per tree. The color of the foliage of this and the subsequent fertilized plots appeared identical with that of Plots 4 and 5 for the first six years of the experiment, but since that time a clear line of demarcation has been seen. The fertilized plots have taken on a darker green color, the leaves are larger and the general appearance of the trees stronger than those in the unfertilized plots. This increased growth of wood should ultimately bring about an increase in the yield.

Plot 7.

This plot receives the following fertilizer per acre:

70 pounds nitrate of soda,
109 pounds acid phosphate,
52.5 pounds sulphate of potash.

The results of this treatment are unsatisfactory so far as a response from fertilizer is concerned, since there has not been any noticeable increase in yield in succeeding years and the trees are not able to surpass in yield the unfertilized trees in Plots 4 and 5. The average yield for the period is 210 pounds per tree or 153.71 bushels per acre. The growth in this like the other fertilized plots has increased during the past few years and averages 9.14 inches per tree which would indicate that the trees were making some use of the additional fertility provided in the fertilizer.

Plot 8.

This plot receives phosphorus in excess of the other plots and receives the following fertilizer per acre:

70 pounds nitrate of soda,
219 pounds acid phosphate,
52.5 pounds sulphate of potash.

This treatment has not resulted in any increased yield over the plots on either side of it. The application is not heavy but sufficiently so to expect a response if the trees were badly in need of this element. The growth is good, averaging 9.18 inches per tree for the ten-year period and has increased from year to year, subject of course to seasonal fluctuations.

Plot 9.

Here we have the following fertilizer applied per acre:

140 pounds nitrate of soda,
109 pounds acid phosphate,
52.5 pounds sulphate of potash.

This plot ranks sixth in yield in the ten-year average and only one year in the period did it rank highest in yield per tree and that was in an off year (1917). The actual yield is 219 pounds per tree on the average or 160.27 bushels per acre which is 62 per cent better than the sod plot and no higher in yield than the unfertilized Plots 4 and 5. In growth the response is seen since this plot averages the highest in growth of any plot in the series. The ten-year average is 9.43 inches per tree in terminal growth and the trees are now considerably larger than those in Plots 4 and 5. The color of the foliage is darker than in any other plot,

being a black green. The cover crop is also a little better each year than in the other plots, which is doubtless due to the fertilizer treatment.

Plot 10.

Here we have an excess of potash over the other plots as follows:

70 pounds nitrate of soda,
109 pounds acid phosphate,
105 pounds sulphate of potash.

This plot stands fourth in yield in the ten-year average and once during the period averaged the highest in yield per tree (1916). The fruit in this plot has always been conceded by those working in the orchard to be the best in quality, that is in size, finish and general appearance. The average yield for the period is 240 pounds per tree or 175.65 bushels per acre, while in twig growth it averaged 9.22 inches per tree which is next to the highest in the series of plots. In size of fruit the plot averages 71 per cent No. 1 fruits which is 5 per cent higher than any other plot, but this must be considered in the light of its bearing, which is less than three of the other plots.

CONCLUSIONS.

From the evidence adduced in the foregoing experiment extending over eleven years the reader might conclude that we do not recommend the use of fertilizers in apple orchards. In the first place it must be clearly understood that this work relates to the use of fertilizers in a *cultivated* orchard only and no data are here presented on the effect of fertilizers in an orchard which is not cultivated. In fact other experiments which will shortly be reported upon show that it is usually necessary to fertilize an apple orchard which is not being cultivated and that returns are almost immediate in that case. On the other hand we do not conclude that it would never pay to fertilize a cultivated apple orchard for doubtless there are soils and conditions where the response would be marked but very often the results are the same as those reported in this experiment—namely that an apple orchard receiving a good system of cultivation responds slowly to the use of chemical fertilizers. Therefore we recommend that

the orchardists of the state apply fertilizers at about the following rate per acre as a trial before they make general use of them:

150 pounds nitrate of soda,
200–300 pounds acid phosphate,
50–100 pounds sulphate or muriate of potash.

If the average observer can see no difference after two or three applications between the fertilized and unfertilized portions of his cultivated orchard it would seem reasonable to wait until the orchard showed some signs of decrease in production or growth before investing heavily in fertilizers. A mature apple tree in this climate should make from seven to nine inches of terminal growth on the average and such an orchard bear on the average at least 75 to 100 barrels per acre (in good seasons of course much more) and the trees should have a healthy green appearance and hold their leaves well into the fall. When these conditions are not maintained then the orchardist should apply additional fertility to the trees.

TABLE No. 8.

Average Number of Fruits per Tree and Average Weight per Tree in Pounds.

Plot 1. To Remain Permanently in Sod. Grass to be Mown when Inconveniently Long and Allowed to Remain. No Fertilizer to be Applied. Number of Trees, 8. Acreage in Plot, .68 A.

Year	Average Number of Apples per Tree												Average Weight of Fruit per Tree in Pounds	
	Picked Apples				Dropped Apples				Totals			Grand Total in No. of Fruits		
	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls		Wt. per Tree: Pounds	Av. Wt. per Apple: Ounces
1908	130	160	33	323	9	62	73	144	139	222	106	467		
1909	13	20	5	38	23	23	11	57	36	43	16	95	23*	3.88
1910	88	78	52	218	72	81	110	263	160	159	162	481	120*	3.88
1911	198	206	56	459	74	174	87	335	272	380	143	795	164	3.30
1912	171	147	29	348	19	8	2	29	190	155	31	376	99	4.21
1913	462	194	1	658	38	33	6	77	500	227	7	734	184	4.01
1914	114	123	8	245	7	8	10	25	121	132	17	270	58	3.44
1915	Crop Destroyed by Frost													
1916	749	241	8	998	51	28	1	80	800	269	9	1078	278	4.13
1917	130	71	1	203	11	9	..	20	141	80	1	223	59	4.23
1918	..	..	..	999	..	..	..	538	..	..	..	1537	373	3.88
10-Yr. Av.				417				142				559	136	

* In 1909 and 1910 the yield was recorded in number of fruits only, hence this figure is calculated from the average weight per apple as recorded in succeeding years.

TABLE No. 9.

Average Number of Fruits per Tree and Average Weight per Tree in Pounds.

Plot 2. Cultivated the Odd Year; Seeded the Even Year. Number of Trees, 16. Acreage in Plot, .55 A.

Year	Average Number of Apples per Tree												Average Weight of Fruit per Tree in Pounds	
	Picked Apples				Dropped Apples				Totals			Grand Total in No. of Fruits	Wt. per Tree: Pounds	Av. Wt. per Apple: Ounces
	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls			
1908	78	49	7	134	7	11	15	33	85	60	22	167		
1909	45	8	1	54	7	3	3	13	52	11	4	67	16*	3.92
1910	369	273	47	690	241	260	58	559	610	533	105	1248	306*	3.92
1911	350	85	17	451	156	79	14	249	506	164	31	701	190	4.34
1912	497	169	32	697	28	19	4	52	525	188	36	749	184	3.93
1913	550	266	1	817	37	65	5	107	587	331	6	924	213	3.69
1914	387	204	4	595	25	81	7	113	412	285	11	708	164	3.70
1915	Crop Destroyed by Frost													
1916	673	412	18	1103	53	46	3	102	726	458	21	1205	303	4.02
1917	46	61	2	109	15	14	. . .	29	61	75	2	138	33	3.83
1918				329				357				686	168	3.92
10-Yr. Av.				484				158				642	157	

* Calculated.

TABLE No. 10.

Average Number of Fruits per Tree and Average Weight per Tree in Pounds.

Plot 8. Cultivated the Even Year; Seeded the Odd Year. Number of Trees, 7. Acreage in Plot, .55 A.

Year	Average Number of Apples per Tree												Average Weight of Fruit per Tree in Pounds	
	Picked Apples				Dropped Apples				Totals			Grand Total in No. of Fruits		
	No. 1	No. 2	ulls	Total	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls		Wt. per Tree: Pounds	Av. Wt. per Apple: Ounces
1908	60	27	5	92	5	8	13	26	65	35	18	118		
1909	23	1	2	26	49	14	12	75	72	15	14	101	27*	4.29
1910	906	514	76	1495	400	307	110	817	1306	821	186	2313	620*	4.29
1911	67	4	11	82	42	18	13	73	109	22	24	154	39	4.08
1912	714	333	53	1100	63	55	14	132	777	388	67	1232	378	4.91
1913	207	30	..	237	22	13	1	36	229	43	1	273	77	4.50
1914	731	451	30	1212	256	247	9	512	987	698	39	1724	416	3.86
1915	Crop Destroyed by Frost													
1916	1041	420	13	1474	66	26	3	95	1107	446	16	1569	434	4.42
1917	3	1	..	4	..	1	..	2	3	2	..	6	2	4.00
1918	..	..	..	525	..	..	..	448	..	..	..	973	261	4.29
10-Yr. Av.				616				218				834	225	

* Calculated.

TABLE No. 11.

Average Number of Fruits per Tree and Average Weight per Tree in Pounds.

Plot 4. Clean Culture. No Cover Crops; no Fertilizer. Number of Trees, 14. Acreage in Plot, .55 A.

Year	Average Number of Apples per Tree												Average Weight of Fruit per Tree in Pounds	
	Picked Apples				Dropped Apples				Totals			Grand Total in No. of Fruits	Wt. per Tree: Pounds	Av. Wt. per Apple: Ounces
	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls			
1908	45	31	4	80	5	7	13	25	50	38	17	105		
1909	38	3	3	44	41	8	13	62	79	11	16	106	26*	3.94
1910	765	507	49	1321	188	273	77	538	953	780	126	1859	451*	3.94
1911	230	54	45	329	113	50	57	220	343	104	102	549	122	3.55
1912	878	844	88	1810	115	147	33	295	993	991	121	2105	459	3.49
1913	262	57	..	320	27	23	1	51	289	80	2	371	100	4.30
1914	720	715	14	1449	703	635	73	1411	1423	1350	86	2859	669	3.74
1915	Crop Destroyed by Frost													
1916	1033	426	33	1492	99	32	5	136	1132	458	38	1628	467	4.59
1917	97	55	..	152	18	15	..	33	115	70	..	185	46	3.98
1918	..	..	..	516	..	..	..	632	..	..	..	1148	283	3.94
10-Yr. Av.				743				338				1081	262	

* Calculated.

TABLE No. 12.

Average Number of Fruits per Tree and Average Weight per Tree in Pounds.

Plot 5. Cultivation and Cover Crop. Number of Trees, 17. Acreage in Plot, .55 A.

Year	Average Number of Apples per Tree												Average Weight of Fruit per Tree in Pounds	
	Picked Apples				Dropped Apples				Totals			Grand Total in No. of Fruits	Wt. per Tree: Pounds	Av. Wt. per Apple: Ounces
	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls			
1908	23	24	9	56	3	8	10	21	26	32	19	77		
1909	27	4	1	32	36	7	5	48	63	11	6	80	21*	4.26
1910	763	786	127	1676	328	336	41	705	1091	1122	168	2381	634*	4.26
1911	35	11	8	54	32	5	8	45	67	16	16	99	29	4.76
1912	922	739	82	1743	164	232	23	419	1086	971	105	2162	501	3.70
1913	81	8	..	89	6	2	..	9	88	10	..	99	27	4.41
1914	1001	559	12	1572	678	480	5	1163	1679	1039	19	2737	647	3.77
1915	Crop Destroyed by Frost													
1916	1044	403	27	1474	155	62	7	224	1199	465	34	1698	472	4.68
1917	36	26	..	62	7	10	..	17	43	36	..	79	21	4.25
1918	..	..	..	533	..	..	..	706	..	..	..	1239	330	4.26
10-Yr. Av.				723				334				1057	268	

* Calculated.

TABLE No. 13.

Average Number of Fruits per Tree and Average Weight per Tree in Pounds.

Plot 6. Cover Crops. Complete Fertilizer. Number of Trees, 26. Acreage, .86 A.

Year	Average Number of Apples per Tree												Average Weight of Fruit per Tree in Pounds	
	Picked Apples				Dropped Apples				Totals			Grand Total in No. of Fruits	Wt. per Tree: Pounds	Av. Wt. per Apple: Ounces
	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls			
1908	24	20	3	47	2	9	9	20	26	29	12	67		
1909	22	2	..	24	22	4	6	32	44	6	6	56	15*	4.31
1910	822	395	56	1273	253	258	58	569	1075	653	114	1842	496*	4.31
1911	129	19	17	165	51	17	15	83	180	36	32	248	77	4.96
1912	1056	549	36	1641	159	215	23	397	1215	764	59	2038	506	3.97
1913	116	9	..	124	9	3	..	12	125	12	..	136	41	4.88
1914	577	562	19	1158	816	1000	12	1828	1393	1562	31	2986	682	3.65
1915	Crop Destroyed by Frost													
1916	722	294	83	1099	220	109	51	380	942	403	134	1479	416	4.50
1917	118	77	3	198	44	35	..	79	162	112	3	278	68	3.91
1918	..	..	..	422	..	..	..	632	..	..	..	1054	284	4.31
10-Yr. Av.				610				401				1001	258	

* Calculated.

TABLE No. 14.

Average Number of Fruits per Tree and Average Weight per Tree in Pounds.

Plot 7. Complete Fertilizer. Cover Crops. Number of Trees, 21. Acreage, .52 A.

Year	Average Number of Apples per Tree												Average Weight of Fruit per Tree in Pounds	
	Picked Apples				Dropped Apples				Totals			Grand Total in No. of Fruits		
	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls		Wt. per Tree: Pounds	Av. Wt. per Apple: Ounces
1908	27	18	1	46	2	7	12	21	29	25	13	67		
1909	21	4	1	26	33	8	4	45	54	12	5	71	18*	4.09
1910	970	418	54	1442	294	232	59	585	1264	650	113	2027	518*	4.09
1911	52	6	9	67	19	10	35	64	71	16	44	131	35	4.32
1912	757	508	35	1300	251	420	75	746	1008	928	110	2046	462	3.61
1913	41	4	..	44	3	1	..	4	44	4	..	48	14	4.67
1914	362	216	9	587	1139	875	10	2024	1501	1091	19	2611	568	3.48
1915	Crop Destroyed by Frost													
1916	470	148	41	659	199	80	26	305	669	228	67	964	301	4.99
1917	120	121	6	247	39	48	1	88	159	169	7	335	73	3.48
1918	..	..	..	186	..	..	..	279	..	..	..	465	119	4.09
10-Yr. Av.				455				414				869	210	

* Calculated.

TABLE No. 15.

Average Number of Fruits per Tree and Average Weight per Tree in Pounds.

Plot 8. Excess Phosphorus. Number of Trees, 19. Acreage in Plot, . 52 A.

Year	Average Number of Apples per Tree												Average Weight of Fruit per Tree in Pounds	
	Picked Apples				Dropped Apples				Totals			Grand Total in No. of Fruits		
	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls		Wt. per Tree: Pounds	Av. Wt. per Apple: Ounces
1908	22	13	1	36	3	7	13	23	25	20	14	59		
1909	27	3	1	31	33	8	6	47	60	11	7	78	20*	4.15
1910	759	348	34	1141	321	223	51	595	1080	571	85	1736	450*	4.15
1911	77	12	21	110	26	19	30	75	103	31	51	185	52	4.52
1912	790	271	8	1069	186	339	37	562	976	610	45	1631	400	3.92
1913	86	6	..	92	16	4	..	21	103	11	..	114	33	4.67
1914	276	263	10	549	963	615	4	1582	1239	878	14	2132	477	3.58
1915	Crop Destroyed by Frost													
1916	567	195	48	810	216	103	19	338	783	298	67	1148	339	4.72
1917	167	162	3	332	68	63	5	136	235	225	8	468	108	3.48
1918	..	..	..	128	..	..	..	300	..	..	..	428	111	4.15
10-Yr. Av.				426				366				792	199	

* Calculated.

TABLE No. 16.

Average Number of Fruits per Tree and Average Weight per Tree in Pounds.

Plot 9. Excess Nitrogen. Number of Trees, 21. Acreage in Plot, .52 A.

Year	Average Number of Apples per Tree												Average Weight of Fruit per Tree in Pounds	
	Picked Apples				Dropped Apples				Totals			Grand Total in No. of Fruits		
	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls		Wt. per Tree: Pounds	Av. Wt. per Apple: Ounces
1908	63	12	..	75	8	9	14	31	71	21	14	106		
1909	22	2	1	25	49	8	8	65	71	10	9	90	23*	4.19
1910	901	314	23	1238	392	54	54	500	1293	368	77	1738	455*	4.19
1911	61	7	18	86	30	24	24	78	91	31	42	164	42	4.14
1912	729	152	9	890	322	279	39	640	1051	431	48	1530	48	5.04
1913	59	5	..	64	13	5	..	19	72	10	..	82	23	4.49
1914	280	131	6	417	1470	1074	2	2546	1750	1205	8	2963	657	3.55
1915	Crop Destroyed by Frost													
1916	498	154	7	659	532	151	..	683	1030	305	7	1342	336	4.03
1917	240	191	1	432	104	94	8	206	344	285	9	638	155	3.88
1918	..	..	..	125	..	..	..	280	..	..	..	405	106	4.19
10-Yr. Av.				393				502				895	184	

* Calculated.

TABLE No. 17.

Average Number of Fruits per Tree and Average Weight per Tree in Pounds.

Plot 10. Excess Potassium. Number of Trees, 17. Acreage in Plot, .48 A.

Year	Average Number of Apples per Tree												Average Weight of Fruit per Tree in Pounds	
	Picked Apples				Dropped Apples				Totals			Grand Total in No. of Fruits	Wt. per Tree: Pounds	Av. Wt. per Apple: Ounces
	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls	Total	No. 1	No. 2	Culls			
1908	82	15	4	101	7	9	7	23	89	24	11	124		
1909	16	..	..	16	10	1	1	12	26	1	1	28	8*	4.81
1910	1171	186	14	1371	305	299	63	667	1476	485	77	2038	612*	4.81
1911	42	2	11	55	17	13	9	39	59	15	20	94	29	4.90
1912	688	108	10	806	320	152	6	478	1008	260	16	1284	364	4.53
1913	65	4	..	70	16	4	..	21	81	8	..	91	27	4.81
1914	247	68	4	318	1564	836	19	2419	1811	904	23	2738	664	3.88
1915	Crop Destroyed by Frost													
1916	719	225	7	951	697	248	21	966	1416	473	28	1917	530	4.43
1917	74	32	..	106	92	34	..	126	166	66	..	232	68	4.72
1918	..	..	..	128	..	..	..	228	..	..	..	356	107	4.81
10-Yr. Av.				382				496				878	241	

* Calculated.